

DR

DeepRob

Discussion 8

Prelude to Rigid Body Objects

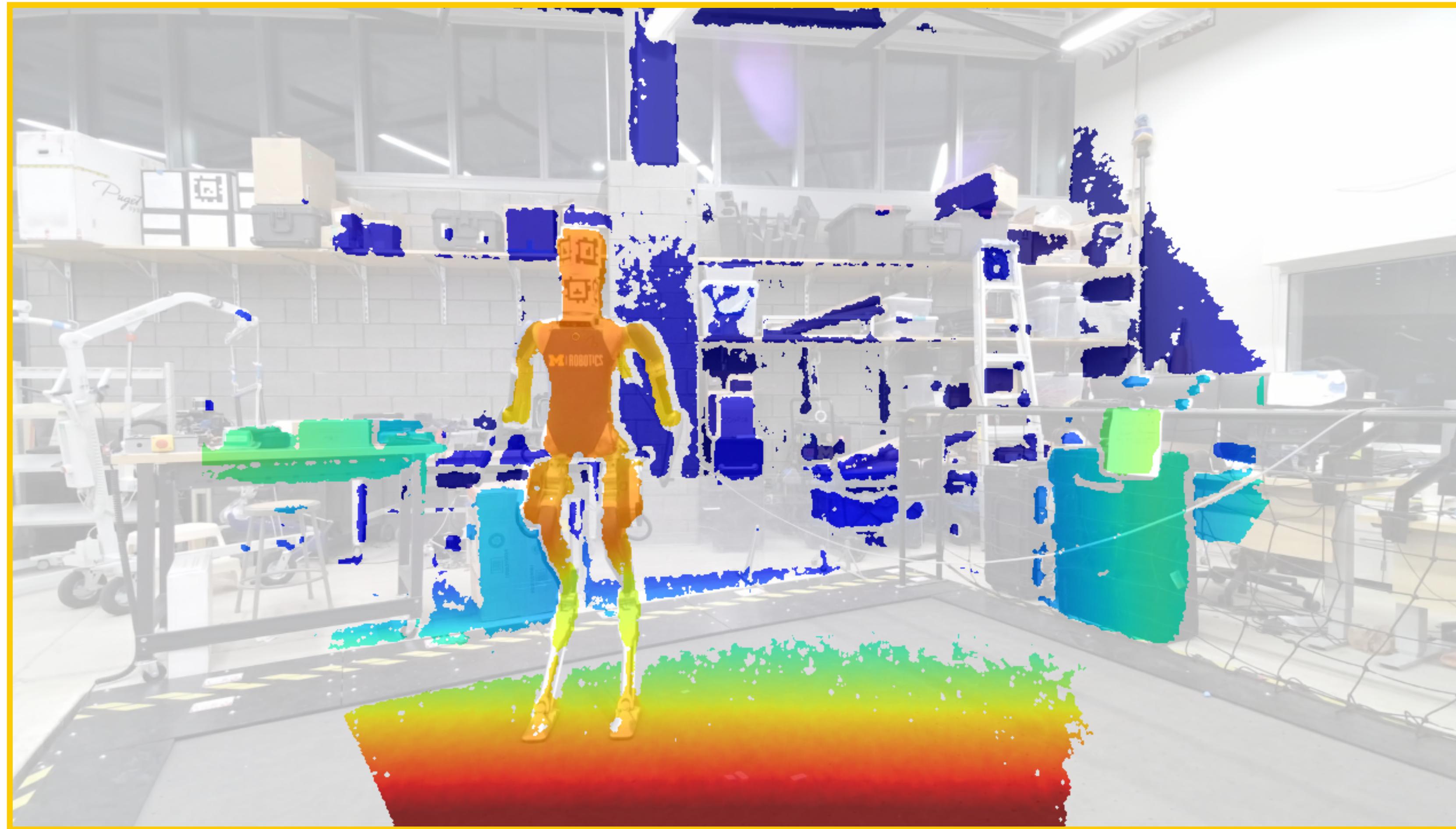
University of Michigan and University of Minnesota



Next Time: Rigid Body Objects

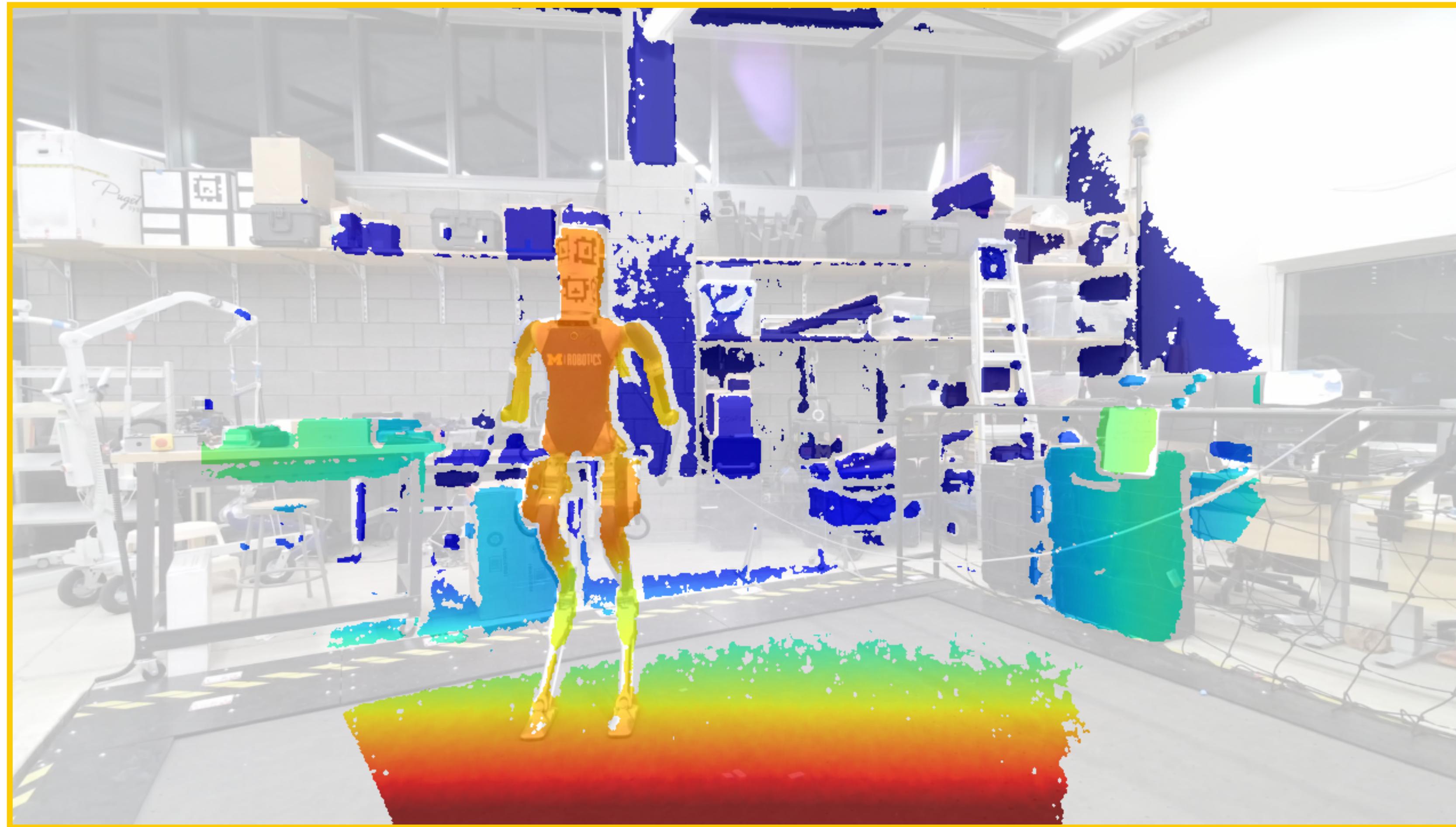
- Seminar 3: Object Pose, Geometry, SDF, Implicit Surfaces
 - 1. [SUM: Sequential scene understanding and manipulation](#), Sui et al., 2017
 - 2. [DeepSDF: Learning Continuous Signed Distance Functions for Shape Representation](#), Park et al., 2019
 - 3. [Implicit surface representations as layers in neural networks](#), Michalkiewicz et al., 2019
 - 4. [iSDF: Real-Time Neural Signed Distance Fields for Robot Perception](#), Oriz et al., 2022
- Seminar 4: Dense Descriptors, Category-level Representations
 - 1. [Dense Object Nets: Learning Dense Visual Object Descriptors By and For Robotic Manipulation](#), Florence et al., 2018
 - 2. [Normalized Object Coordinate Space for Category-Level 6D Object Pose and Size Estimation](#), Wang et al., 2019
 - 3. [kPAM: KeyPoint Affordances for Category-Level Robotic Manipulation](#), Manuelli et al., 2019
 - 4. [Single-Stage Keypoint-Based Category-Level Object Pose Estimation from an RGB Image](#), Lin et al., 2022

Last Time: 3D Perception



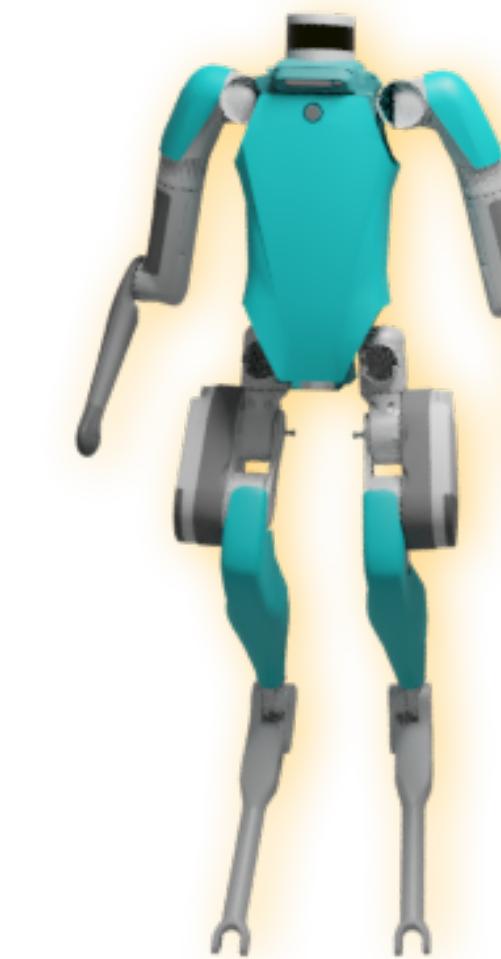
Data courtesy of [Anthony Opiari](#), [Liz Olson](#), [Grant Gibson](#), and [Arden Knoll](#)

This Time: Rigid Body Objects

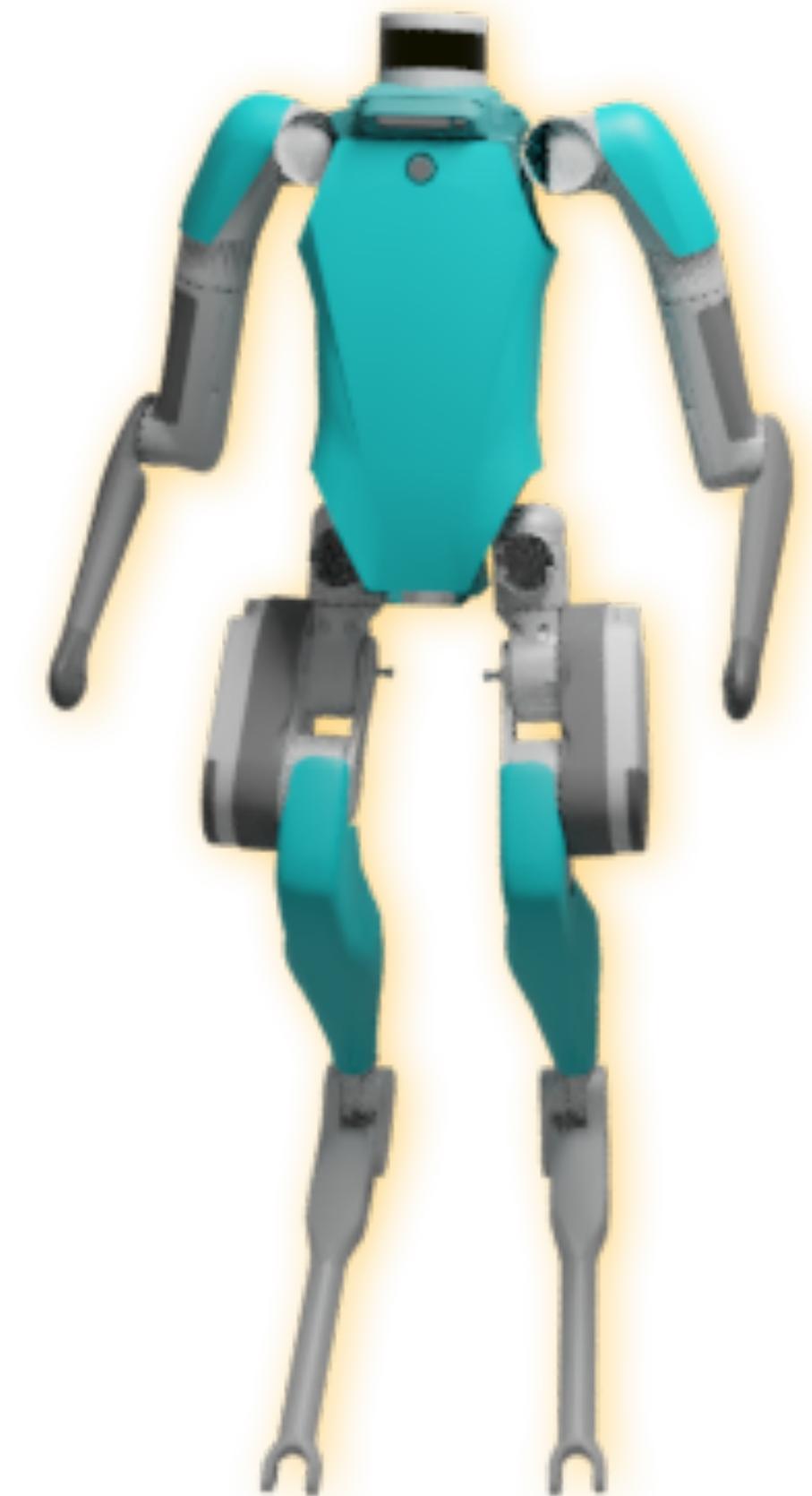


Data courtesy of [Anthony Opiari](#), [Liz Olson](#), [Grant Gibson](#), and [Arden Knoll](#)

This Time: Rigid Body Objects



Example Rigid Body Object

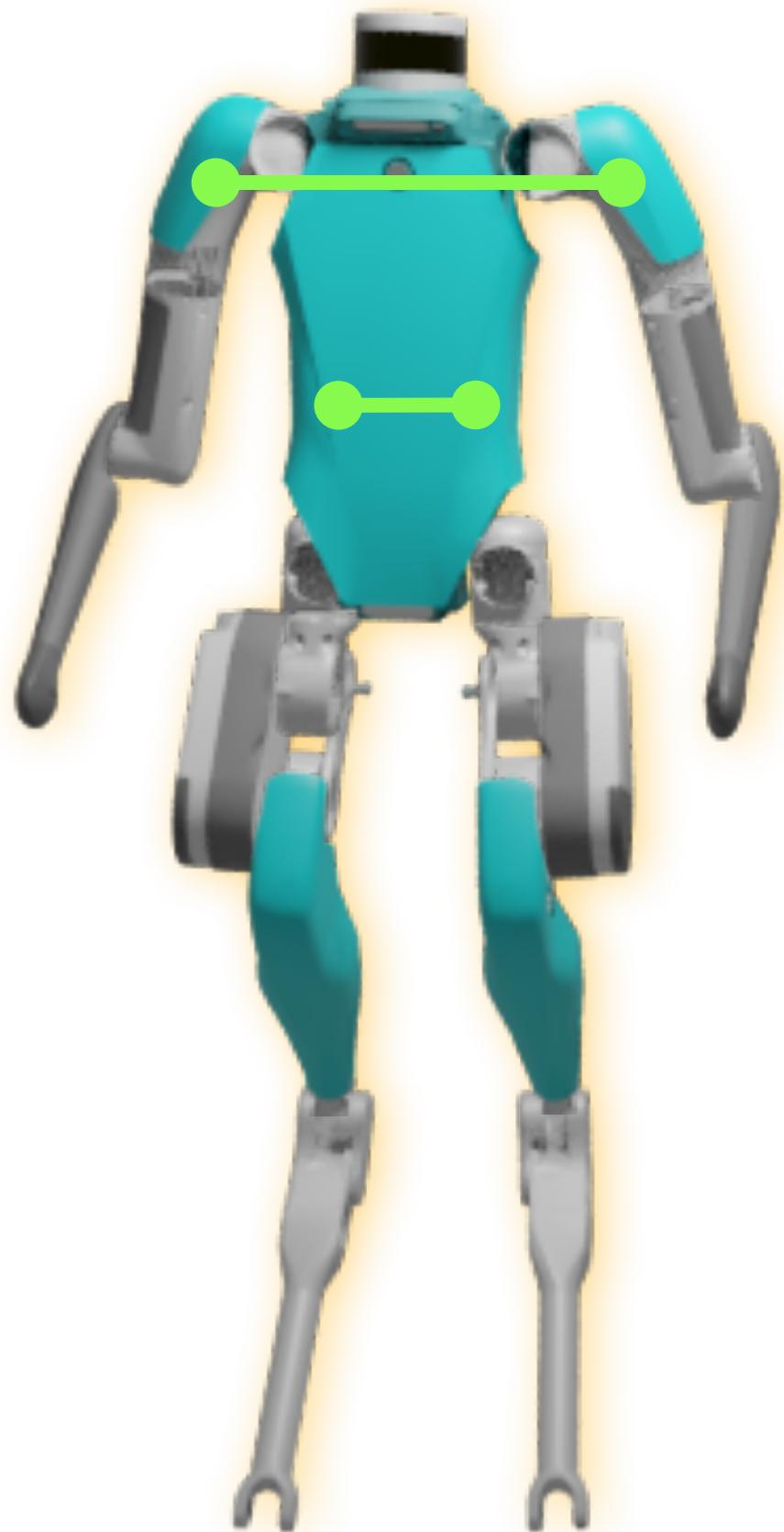


Example Rigid Body Object

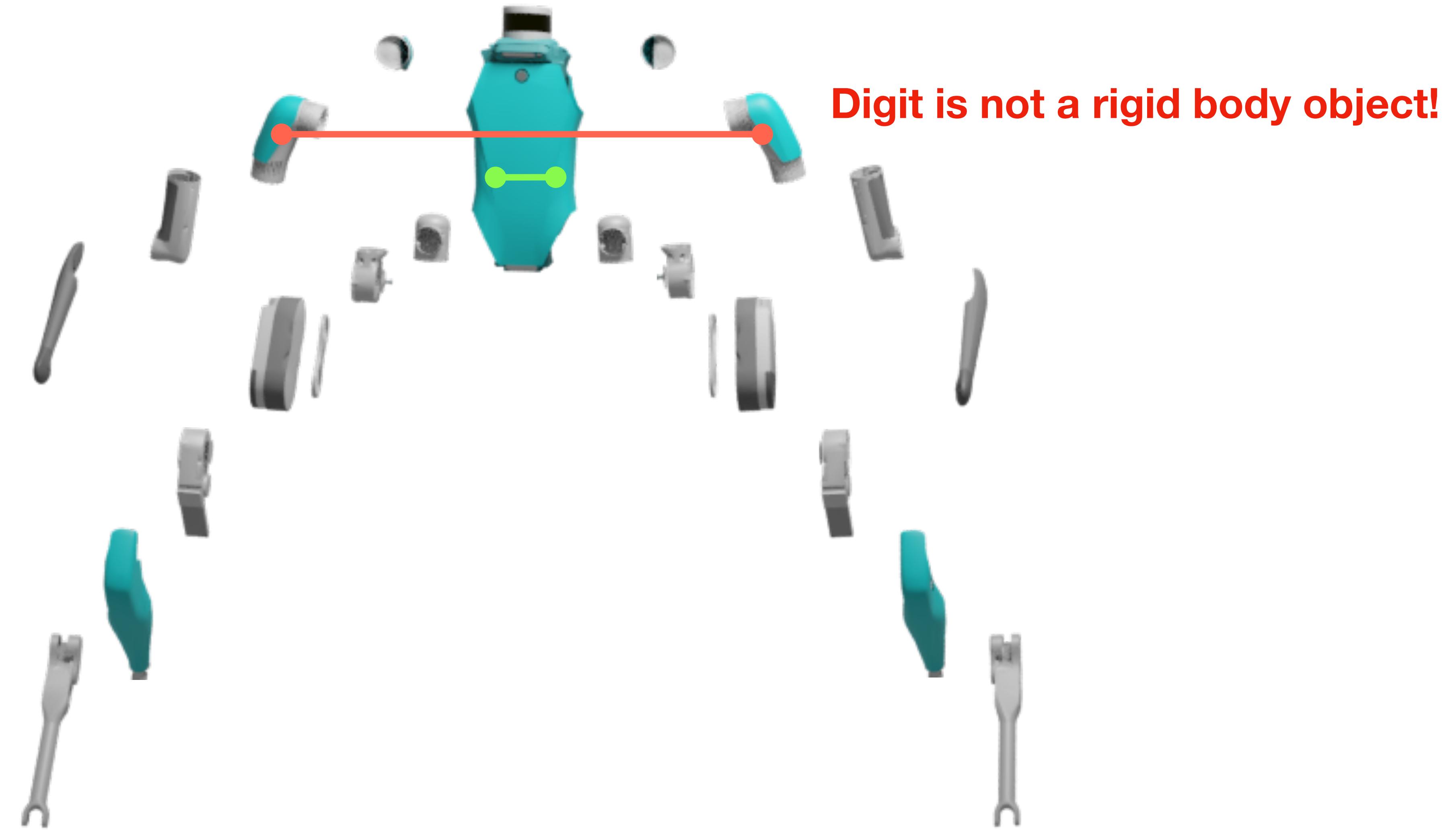
Rigid body:

Model of an object that assumes no deformation is possible

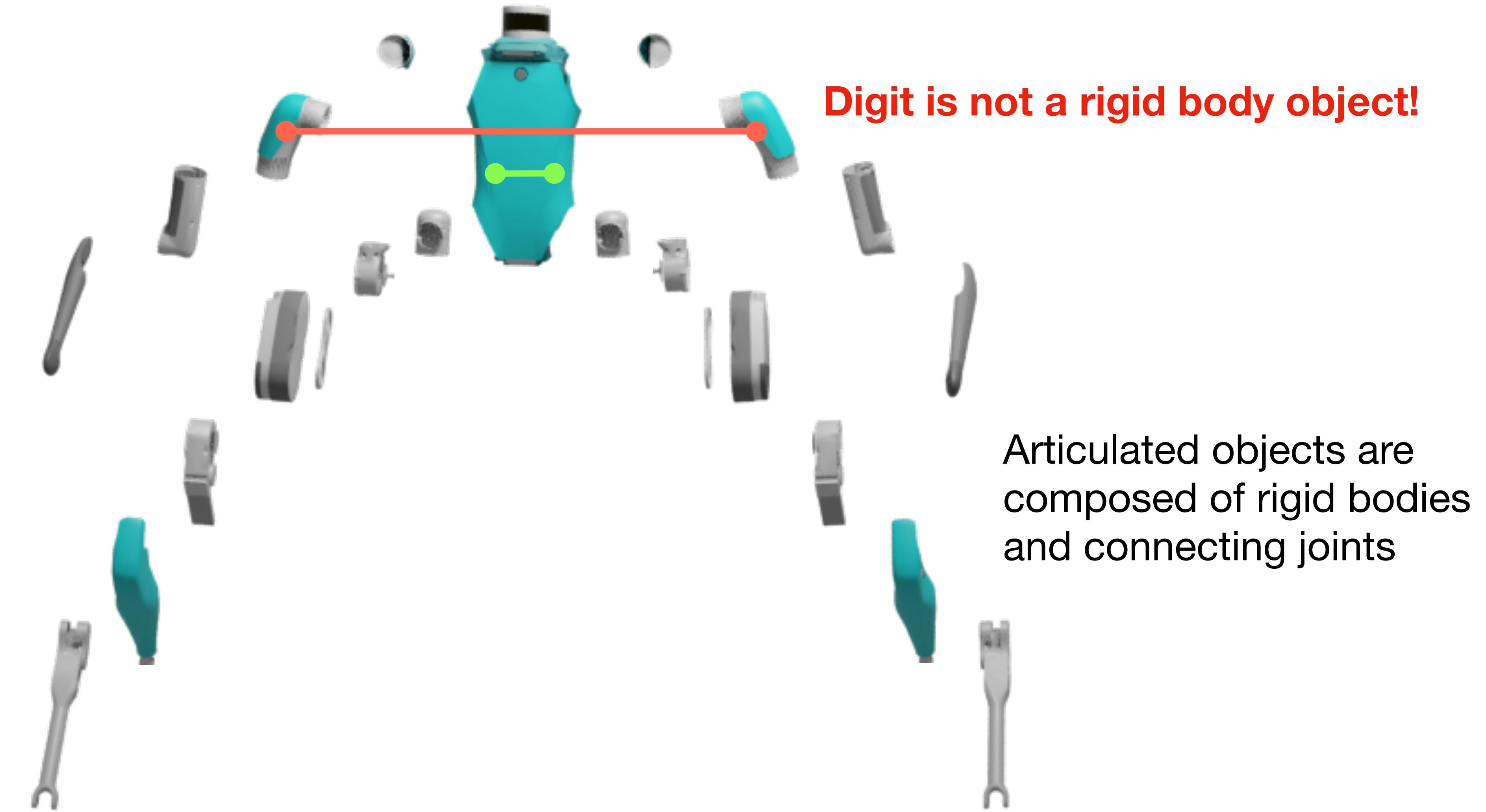
I.e. Every pair of points on the object remain at constant distance



Aside: Digit is an Articulated Object



Aside: Digit is an Articulated Object



Rigid Body Objects



Rigid Body Objects

Rigid body:

Model of an object that assumes no deformation is possible

i.e. Every pair of points on the object remain at constant distance



How to represent the 3D geometry of objects?

What roles can deep learning play?

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

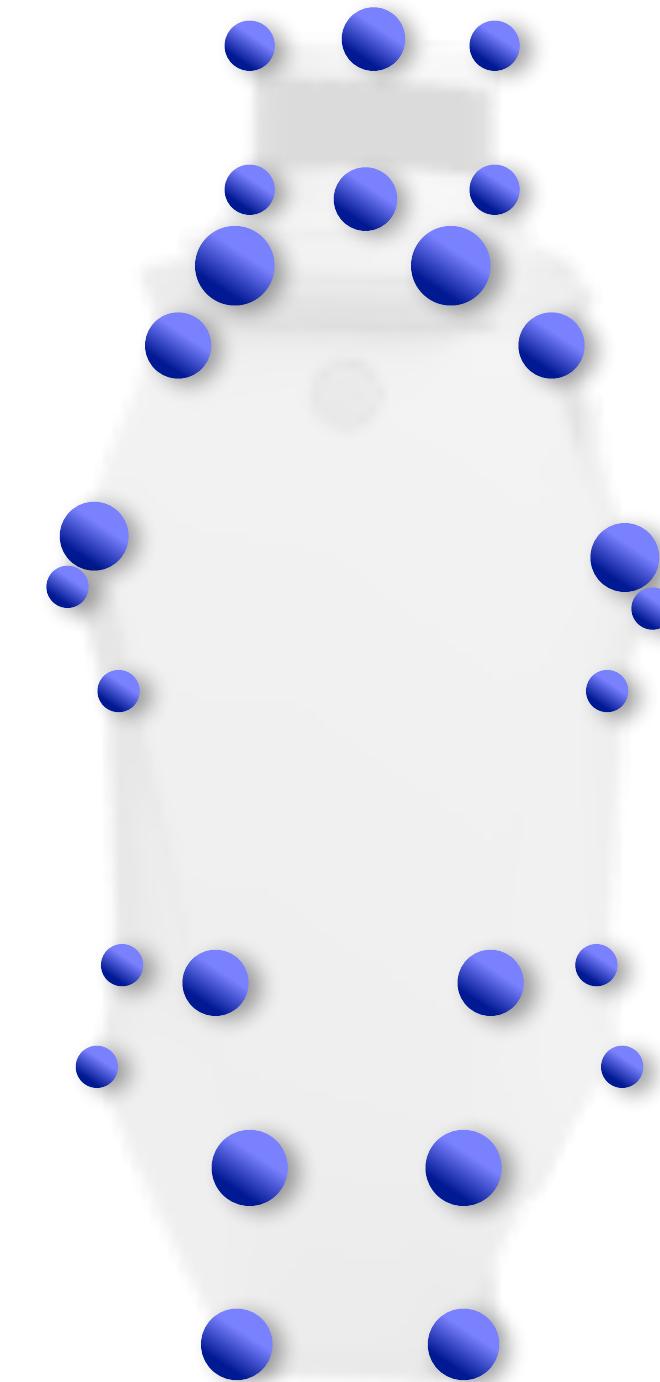


Vertices: set of 3D coordinates

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

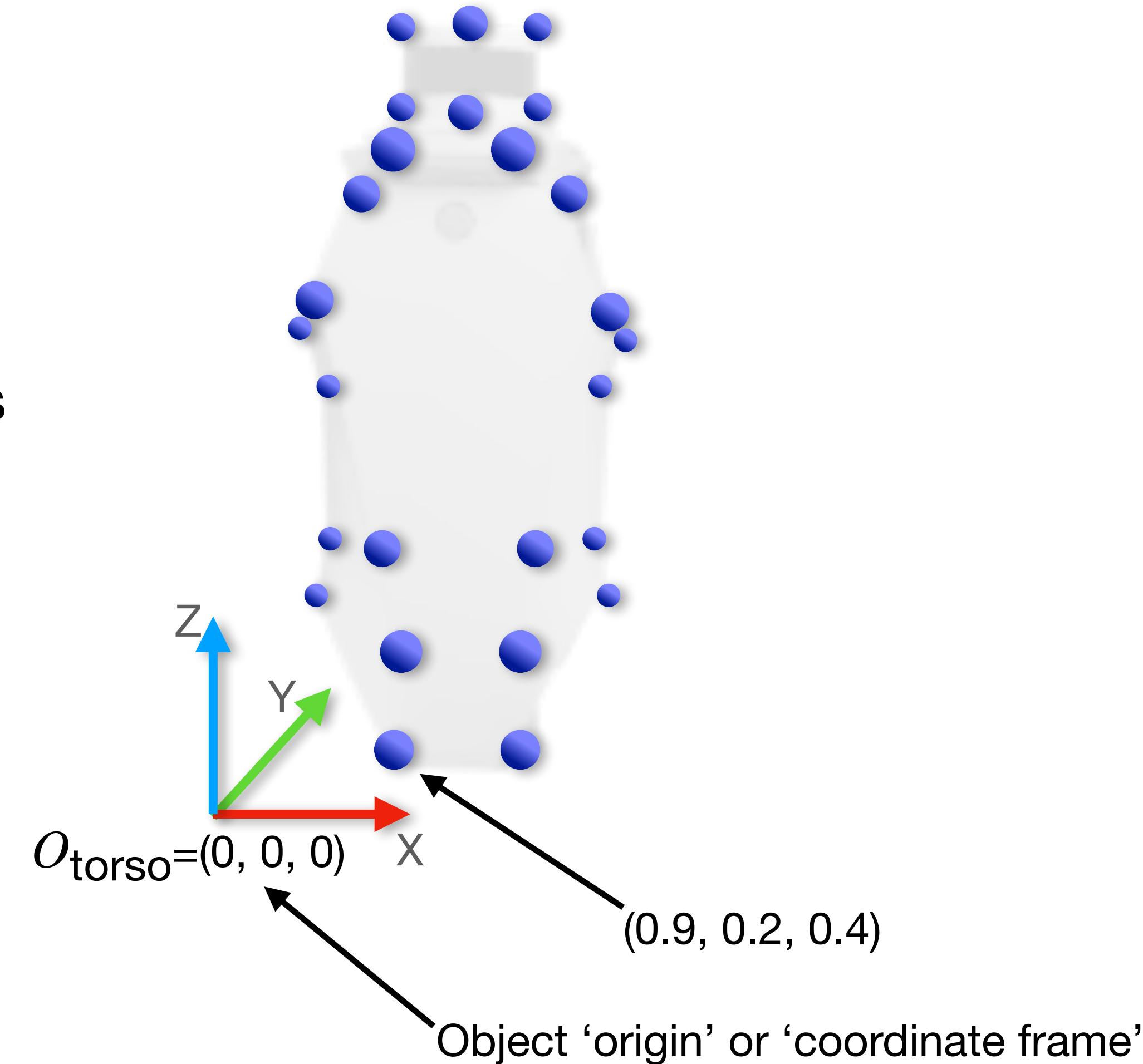
Vertices: set of 3D coordinates



Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

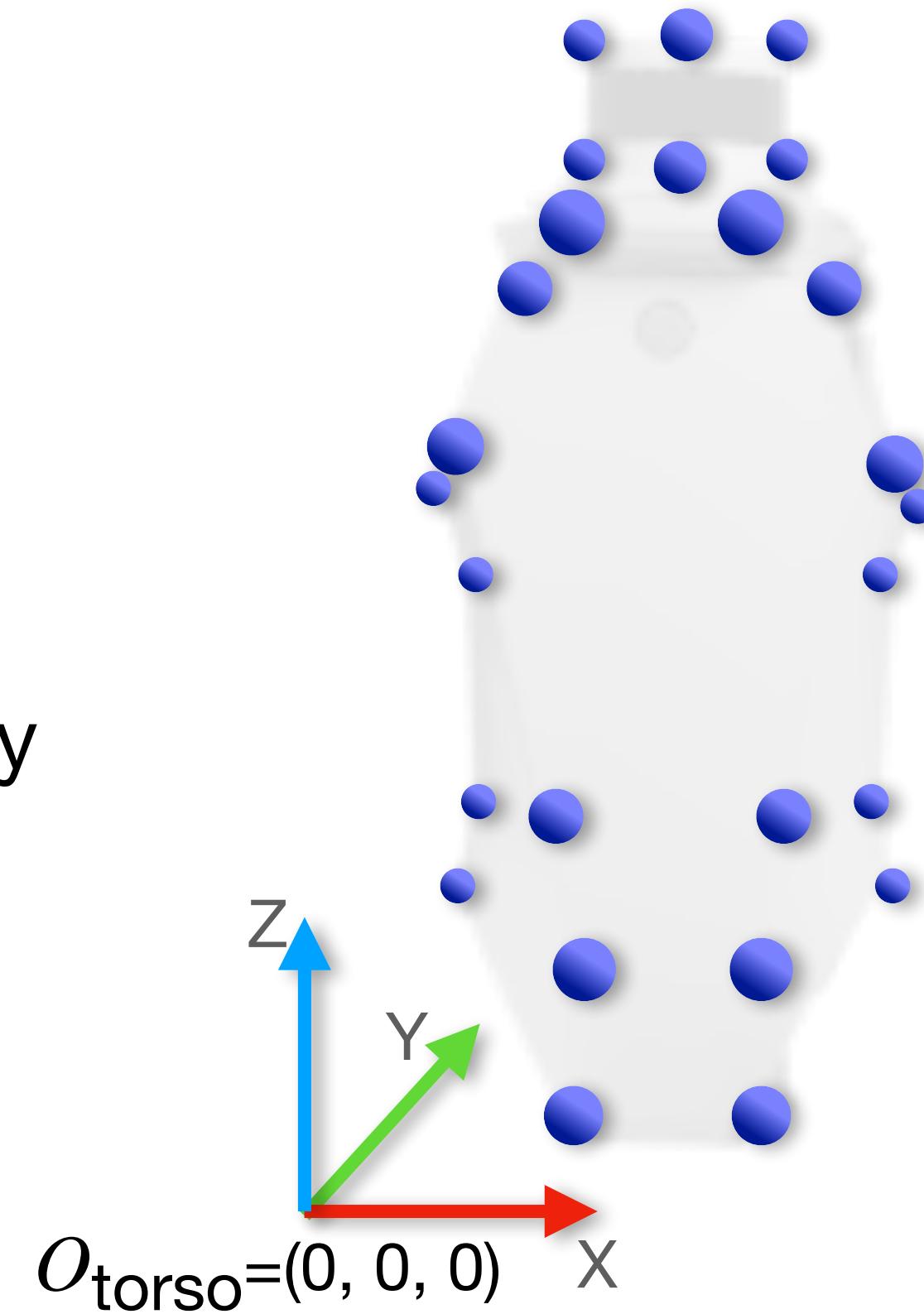


Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

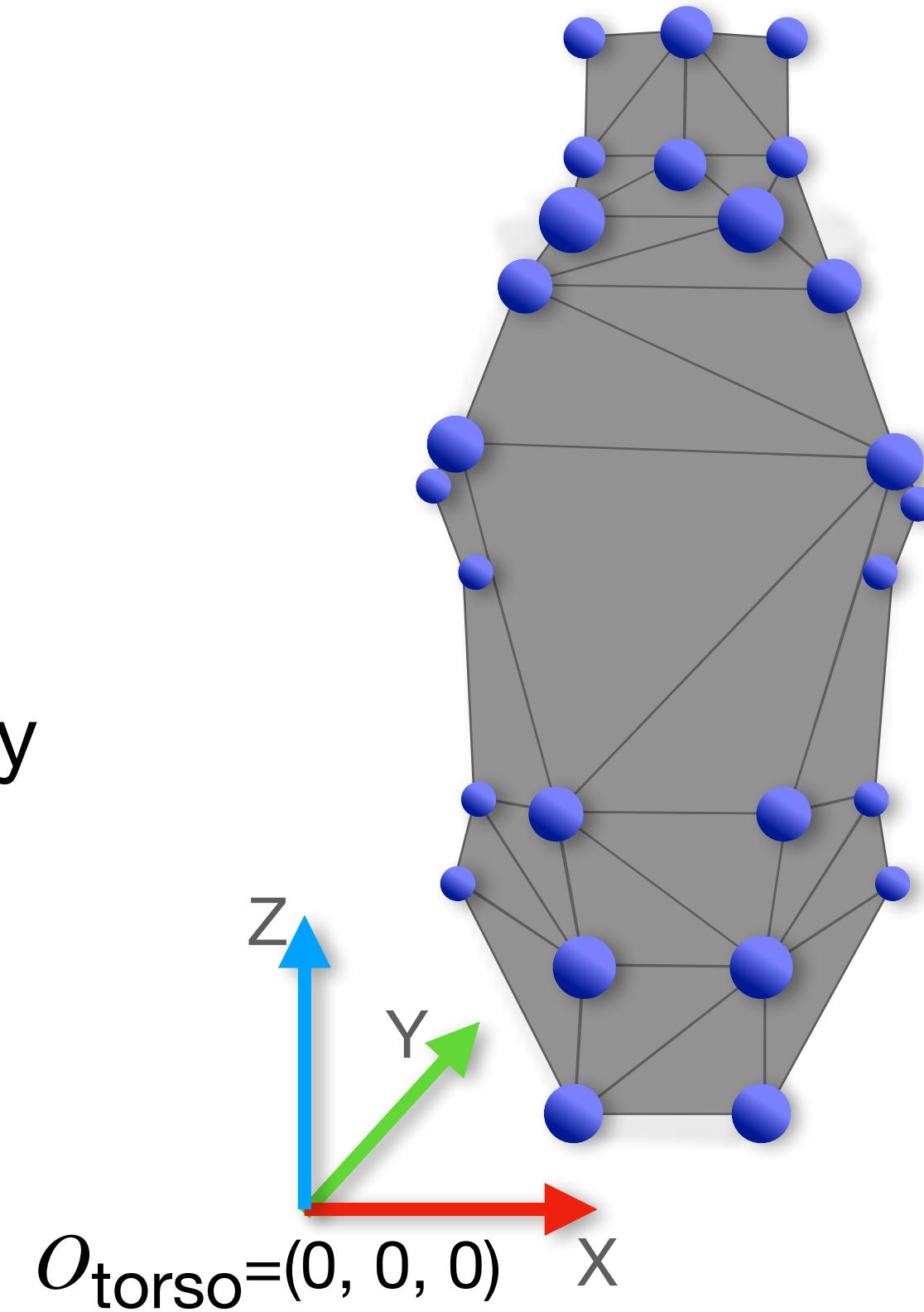


Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

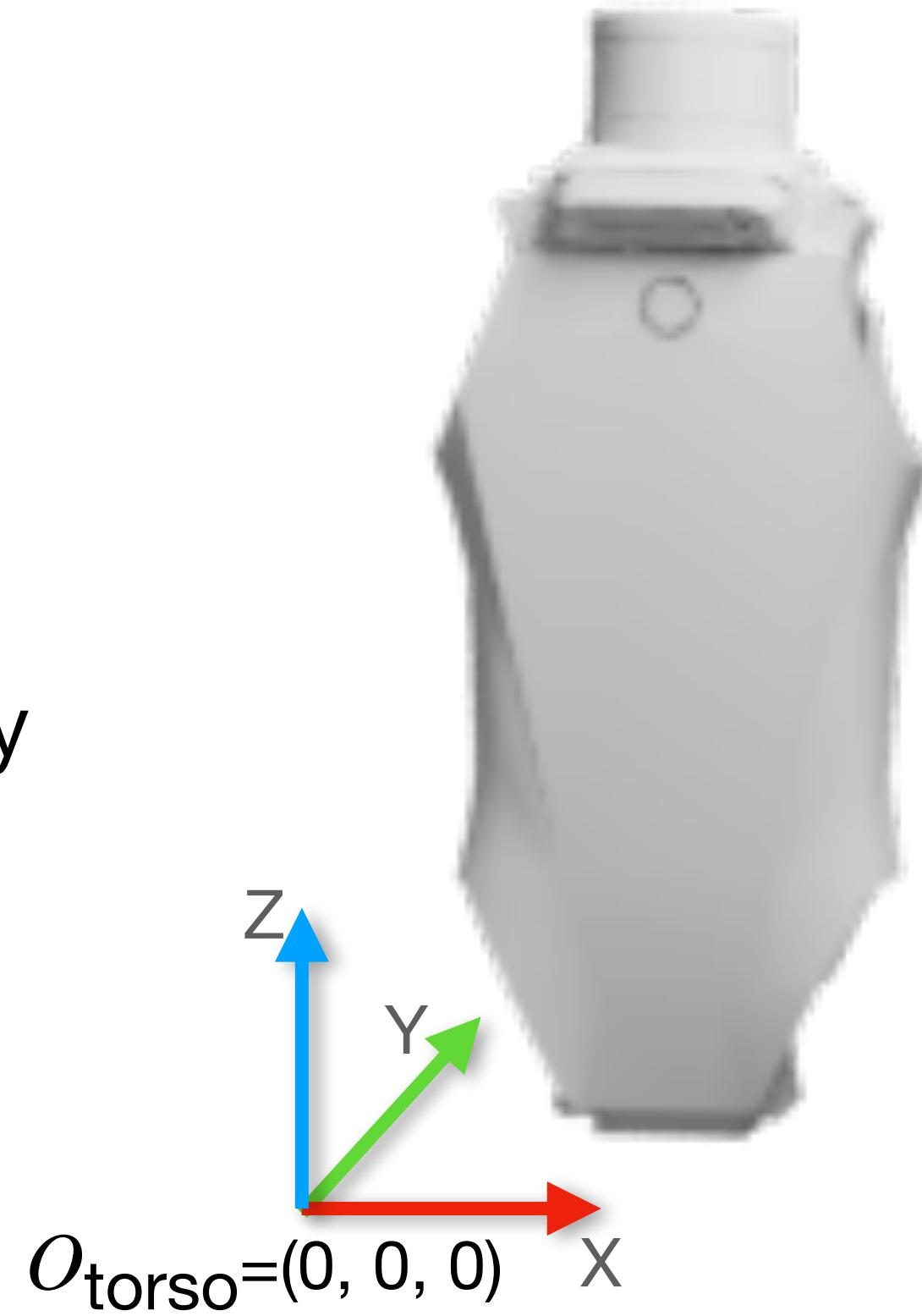


Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices



Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices



Texture

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face



Texture



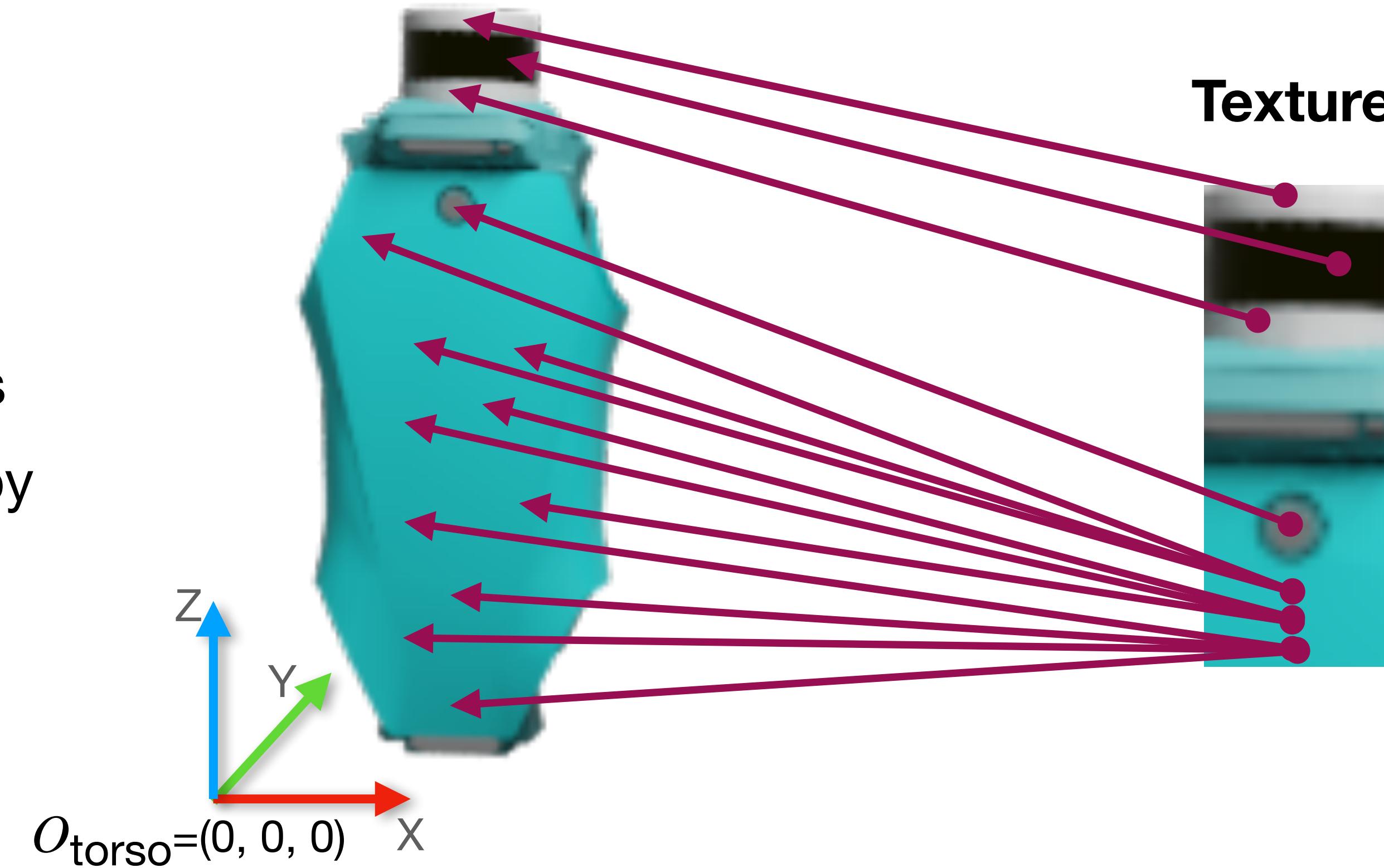
Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face



Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face



Common Geometry File Formats

.obj (wavefront)

.ply (polygon file format)

.stl (standard tessellation language)

.dae (collaborative design activity)

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face



Common Geometry File Formats

.obj (wavefront)

.ply (polygon file format)

.stl (standard tessellation language)

.dae (collaborative design activity)

```
torso.obj
# Blender v2.92.0 OBJ File: ''
# www.blender.org
mtllib torso.mtl
o _TMPOBJ TMPMESH_.002
v -0.008115 0.069371 0.399356
v -0.007999 0.062997 0.404000
v -0.007999 0.070006 0.400481
v -0.083020 0.080245 0.186004
:
f 1//1 2//1 3//1
f 4//2 5//2 6//2
f 561//3 562//3 563//3
f 727//4 728//4 729//4
f 730//4 731//4 732//4
f 733//4 734//4 735//4
```

Texture file

Vertices

Faces

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face

Where are geometry definitions from?

Human artists (e.g. [Sketchfab](#), [cgtrader](#))

Photogrammetry algorithms (e.g. [Matterport](#))



Rigid Body Objects: Pose

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face



Rigid Body Objects: Pose

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face

Pose: Position and orientation of object coordinate frame in world coordinate frame



Rigid Body Objects: Pose

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face

Pose: Position and orientation of object coordinate frame in world coordinate frame



Rigid Body Objects: Pose

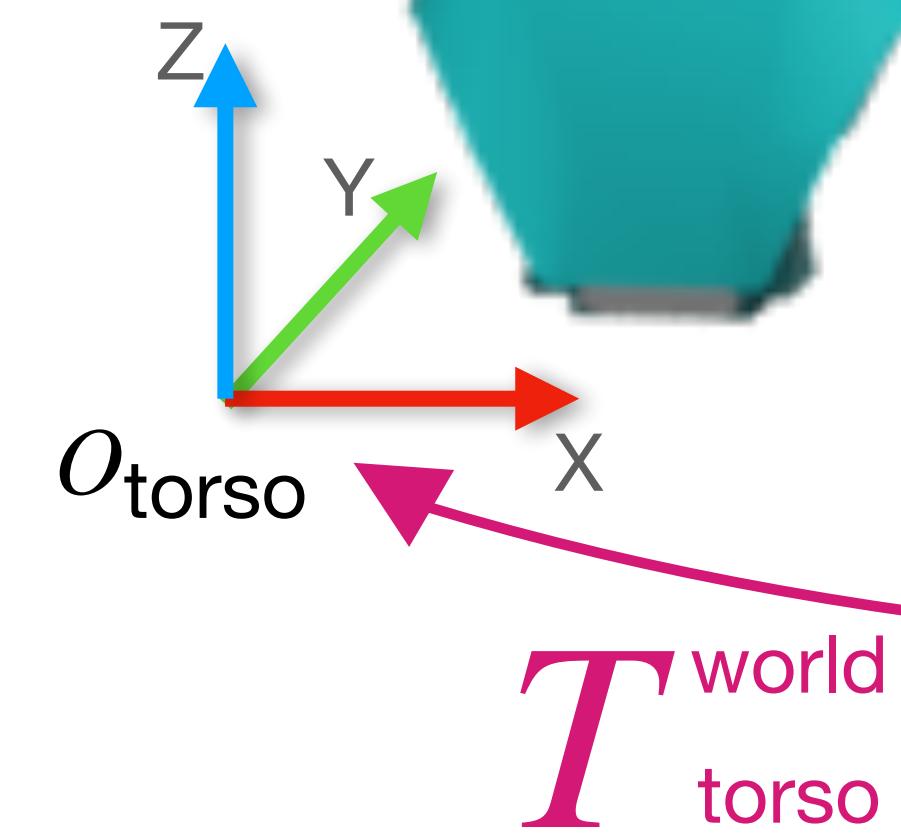
How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices

Texture Map: Map from image pixel on texture to object face

Pose: Position and orientation of object coordinate frame in world coordinate frame



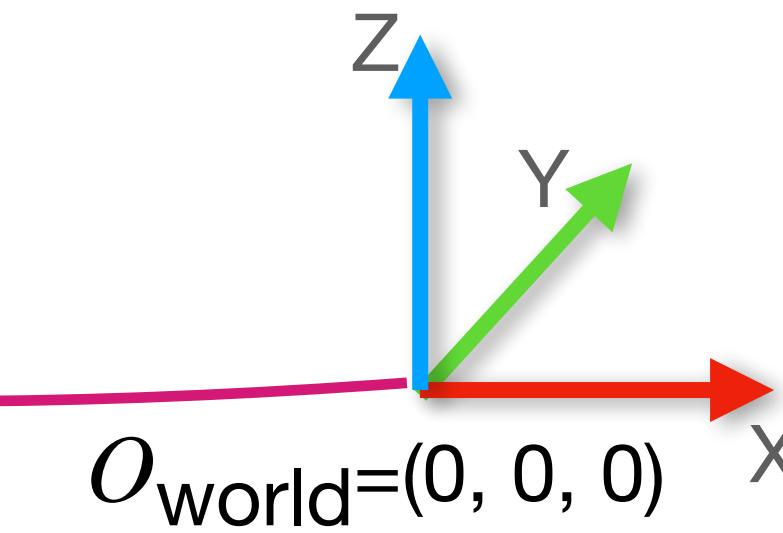
Rigid Body Transformations

From Special Euclidean group, SE(3), meaning they preserve Euclidean distance

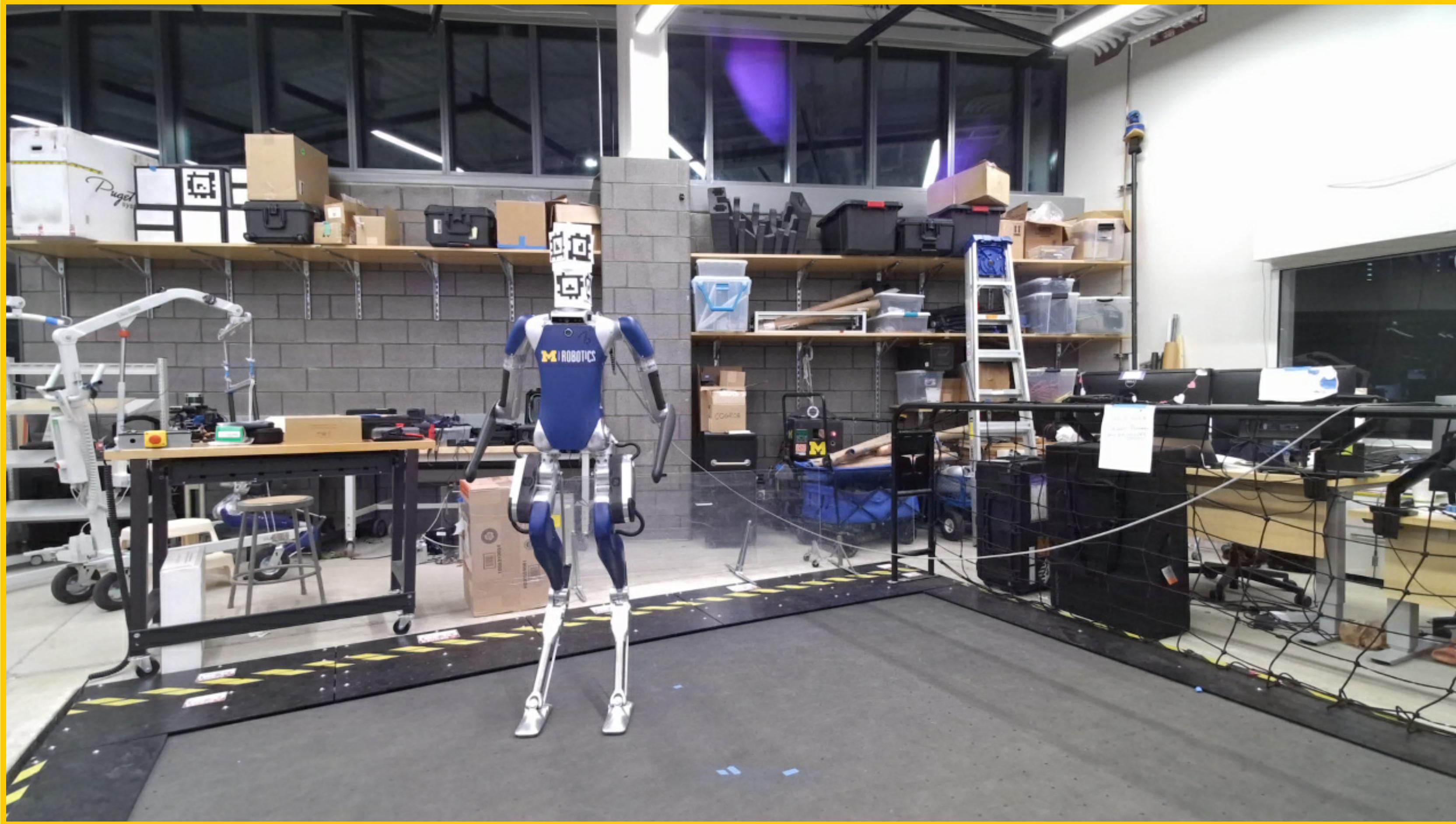
Can be decomposed into a rotation (3DoF) followed by a translation transform (3DoF)

Rotations commonly expressed as quaternions

Translations expressed as residuals (deltas)

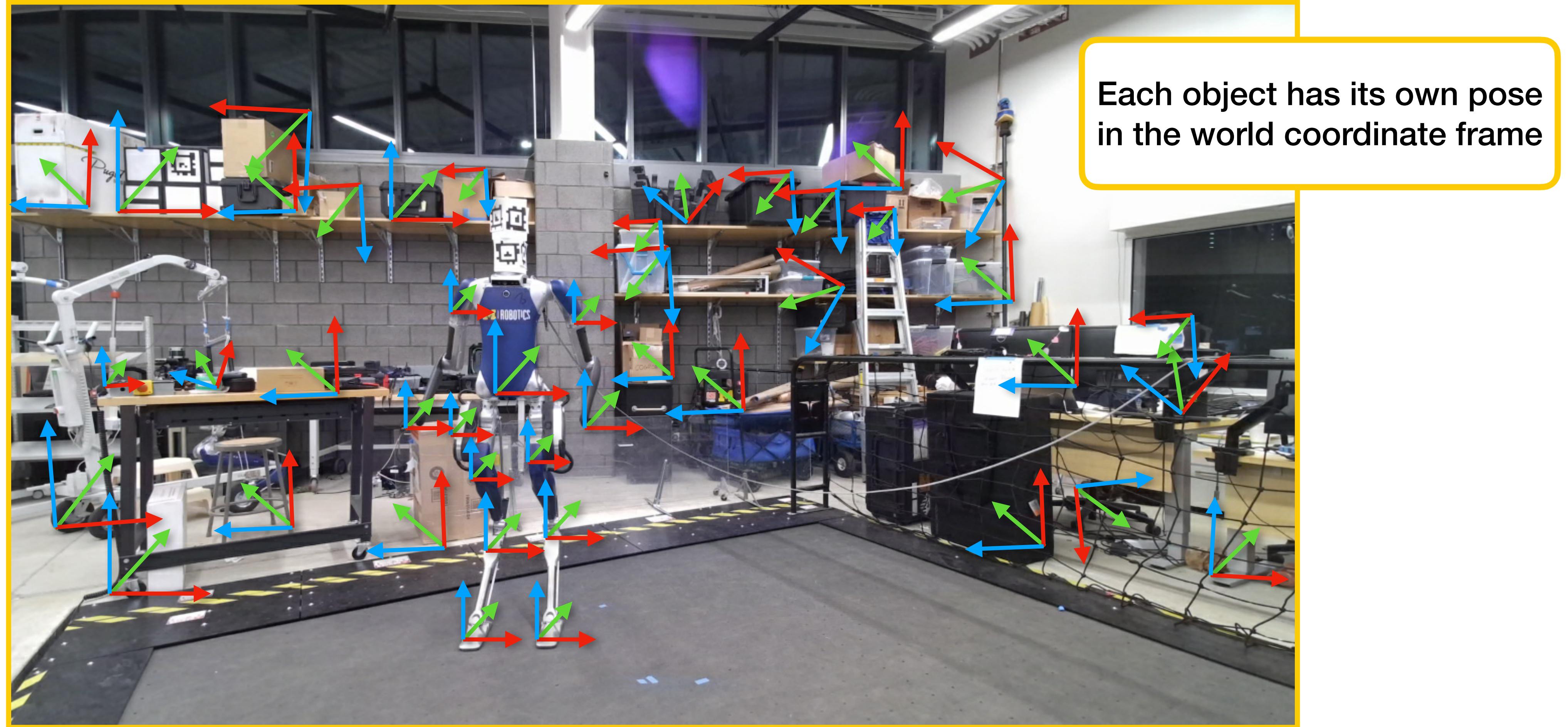


Collections of Rigid Body Objects



Data courtesy of [Anthony Opiari](#), [Liz Olson](#), [Grant Gibson](#), and [Arden Knoll](#)

Collections of Rigid Body Objects



Explicit Object Representations are Useful for Model-Driven Robotics

Knowing object geometry and pose enables

- Collision-free motion planning
- Path planning and obstacle avoidance
- Task planning
- Goal-directed manipulation

Rigid Body Objects: Roles for Deep Learning

- 6DoF pose estimation
 - How to perceive from vision or tactile sensors?
- Implicit surfaces and signed distance functions
 - How to model an object's surface *implicitly* by a learned network?
- Dense object descriptors
 - How to extract features from a learned network that describe local and global object properties?
- Category-level representations
 - How to model geometry and pose for objects of varying shape but same semantic category?

Next Time: Rigid Body Objects

- Seminar 3: Object Pose, Geometry, SDF, Implicit Surfaces
 1. [SUM: Sequential scene understanding and manipulation](#), Sui et al., 2017
 2. [DeepSDF: Learning Continuous Signed Distance Functions for Shape Representation](#), Park et al., 2019
 3. [Implicit surface representations as layers in neural networks](#), Michalkiewicz et al., 2019
 4. [iSDF: Real-Time Neural Signed Distance Fields for Robot Perception](#), Oriz et al., 2022
- Seminar 4: Dense Descriptors, Category-level Representations
 1. [Dense Object Nets: Learning Dense Visual Object Descriptors By and For Robotic Manipulation](#), Florence et al., 2018
 2. [Normalized Object Coordinate Space for Category-Level 6D Object Pose and Size Estimation](#), Wang et al., 2019
 3. [kPAM: KeyPoint Affordances for Category-Level Robotic Manipulation](#), Manuelli et al., 2019
 4. [Single-Stage Keypoint-Based Category-Level Object Pose Estimation from an RGB Image](#), Lin et al., 2022

DR

DeepRob

Discussion 8

Prelude to Rigid Body Objects

University of Michigan and University of Minnesota

